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Metal-contaminated indoor and outdoor housedust from a neighborhood Smelter area in Torreón, Mexico

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Abstract

In this study environmental samples (aerosols, indoor and outdoor dust samples) were taken within a >100 km^2 area surrounding the smelter in Torreón (NE México). Samples were analyzed for Cd, Pb and Zn concentrations using trace-metal clean techniques. Results in outdoor ambient air ranged from 0.7 to 12.6 and 30 to 790 ng m^{-3} of Cd and Zn, respectively. In outdoor dust Cd ranged from 4.2 to 56.2 µg g^{-1} (median 12.6 µg g^{-1}) and Zn from 509 to 16,483 µg g^{-1} (2,451 µg g^{-1}). Concentrations were greatest closest to the smelter and decreased with distance from the smelter, with the highest levels corresponding with the prevailing wind direction. According to the literature, the levels of Cd, Pb and Zn found in the urban area from Torreón could have consequences for human and environmental health.

Keywords: heavy metals, smelter, urban dust, children, health effects

1. Introduction

Despite the recent introduction of some emission controls on smelters in developed and developing countries, the processing of Ag-Cd-Pb-Zn ores continues to pollute the environment and severely affect the health of individuals, especially young children, living in mining and smelter communities. This problem is of special concern in México, which has several large metallurgical complexes, including five lead smelters and refineries that are mainly located in its northern region [1-3]. The largest of those is in the city of Torreón (~577,500 inhabitants), in the center of northern México, where environmental and health public problems have been associated with the metallurgical complex Met-Mex Peñoles S.A. de C.V. ("Met-Mex") that went into production in 1902 and has been in operation for over a century. The facility is a primary silver-zinc-lead-cadmium smelter, which also produces gold, bismuth, sulfuric acid, oleum, and antimony trioxide, is the largest producer of silver in the world, the largest producer of zinc in Latin America, and the most important producer of cadmium, gold, and lead in Mexico [4].

Fugitive emissions from "Met-Mex", which was operating without adequate environmental controls for a century, were found to have contaminated the adjacent community and elevated lead blood (PbB) concentrations of

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the children (10-14). Consequently, in 1999 México's Environmental Protection Agency mandated corporate efforts to reduce that metal pollution and monitor the adjacent environment [5]. This study was designed to provide an independent assessment of the efficacy of those new environmental and human health efforts and to characterize the current level of As, Cd, Pb and Zn pollution in Torreón, México.

2. Materials and methods

Environmental samples were collected within a >110 km^2 grid surrounding the smelter in Torreón. Aerosols were continuously collected over a 14 month period (November 2004 to April 2006) at a monitoring station located ~1 km northeast of the facility. Those aerosols were collected on acid-cleaned PTFE filters (0.45 µm) placed 3 m above ground level, with at a pumping rate of 0.25 L s^{-1} and sampled air volumes of 12-30 m^3. Composite surface soil samples (aliquots of equal amounts from 3-5 locations; 0-2 cm) were collected from public gardens and play areas (n=112). Outdoor dust was collected with surface swipes (1-2 m^2) from cement tile roofs (ca. 3 m above street-level) of 39 houses, because dust provides an indirect measure of air pollution integrated over varying time periods (Davis and Gulson 2005). Indoor dust was collected with established protocols (Lanphear et al. 1999) from window sills in the 22 houses of the children, who lived within the 30 km^2 area surrounding the smelter and were included in this study. Soil and dust samples were oven dried to a constant weight and sieved (<75 µm) in a trace metal clean laboratory. All of the samples were processed and analyzed in HEPA filtered air (Class 1000), trace metal clean laboratories (*35*) using high-purity reagents (trace metal grade) and water (18 MΩ cm; Milli-Q). Aliquots of dried, filtered (<75 µm) dust samples were digested with 10 mL concentrated HNO_3:HCl (10 mL 3:1 v/v) and 2 mL concentrated HF in a block digester at 120°C for 12 hours. Aerosol filters were digested with 10 mL concentrated HNO_3:HCl (3:1 v/v). Digested samples were evaporated to dryness and then dissolved with 1 N HNO_3 for lead concentration measurements.

Lead concentrations in all samples were measured with a Finnigan MAT Element® magnetic sector high-resolution inductively coupled plasma source mass spectrometry (HR-ICP-MS) at UCSC. Lead isotopic compositions for street and outdoor dust were then measured with the HR-ICPMS, along with concurrent analyses of NIST SRM 981 (common lead). The accuracy and precision of those analyses were confirmed by subsequent analyses of a subset of those samples with a Finnegan MAT Neptune® magnetic sector multi-collector, high-resolution inductively coupled plasma source mass spectrometer (MC-ICP-MS).

3. Results

Results in outdoor ambient air ranged from 0.7 to 12.6, 65 to 705 and 30 to 790 ng m^{-3} of Cd, Pb and Zn, respectively (Fig. 1). Higher atmospheric metals concentrations were observed in December 2005 and March 2006 and relatively lower concentrations were observed in October 2005. Figure 2 also shows that the atmospheric Pb deposition outdoor averaged from 30 to 1,350 mg m^{-2} d^{-1}. Highest deposition rates (860-1,350 mg m^{-2} d^{-1}) were always <1 km from the smelter, mainly on the southwest side - downwind from the facility. Further, the rates ranged from 130 to 310 mg m^{-2} d^{-1} at 2 km and from 31-75 mg m^{-2} d^{-1} at >4 km from the smelter. Metals concentrations in outdoor dust ranged from 4.2 to 56.2 mg g^{-1} (median 12.6 mg g^{-1}) for Cd, 150 to 14,365 mg g^{-1} (median 880 mg g^{-1}) for Pb, and 509 to 16,483 mg g^{-1} (2,451 mg g^{-1}) for Zn (Fig. 2). Based on regional background (ranging from <1 to 3, 15 to 35, 20-40 µg g^{-1} for Cd, Pb and Zn), the metal concentrations in the urban environmental from Torreón were 1-3 orders of magnitude contamination. There were significant correlations ($r^2 \geq 0.74$, $p<0.01$) between metal concentrations of soil and outdoor dust with the distance to the smelter and among metal concentrations. Concentrations of Cd, Pb and Zn were greatest closest to smelter and decreased with distance from the smelter, with the highest levels southeast of the smelter corresponding with the prevailing wind direction. In Torreón the prevailing wind directions is from NE to SW and changes during the winter from NW to SE. This implicated to the Met-Mex plant as the source of the metal pollution. The maximum values are 20 to 80 times higher than values in urban dust or residential/parkland soils (3-20, 200-250, and 200-500 µg g^{-1} for Cd, Pb, and Zn, respectively) that has been defined as hazardous to humans by U.S. EPA. Considering the soil quality guidelines for environmental some urban environmental areas in Torreón need urgently a remediation.

Elevated concentrations of Cd, Pb and Zn in the urban environment sites from Torreón (NE, México) could have important consequences for human and environmental health [6-7]. For example, EPA has classified Cd as a Group B1, probable human carcinogen. Renal damage is the most sensitive indicator of toxicity resulting from chronic oral exposure to Cd whilst lung cancer and kidney toxicity have been associated with inhaled Cd. Cd has been linked to other pathologies including diabetes and high blood pressure. Cd is principally a cumulative nephrotoxicant that is poorly eliminated by the body with prolonged exposure resulting in renal dysfunction. Lead in dust and soil at levels of 500 to 1,000 µg g^{-1} begins to affect children's blood lead (PbB) levels. Exposure to Pb has also been found to adversely affect a child's intellectual and academic functioning, to increase risk of antisocial and delinquent behavior. Elevated amounts of Pb increase coronary heart disease mortality in adults. In the case of Zn, low levels are essential for maintaining good health, which is required for proper growth and development of young children. However, exposure to large amounts (>10-15 times more than necessary) can cause stomach cramps, anemia, and changes in cholesterol levels. Inhaling large amounts of zinc (as dusts or fumes) can cause a specific short-term disease called metal fume fever, but the long-term effects of breathing high levels of zinc are unknown.

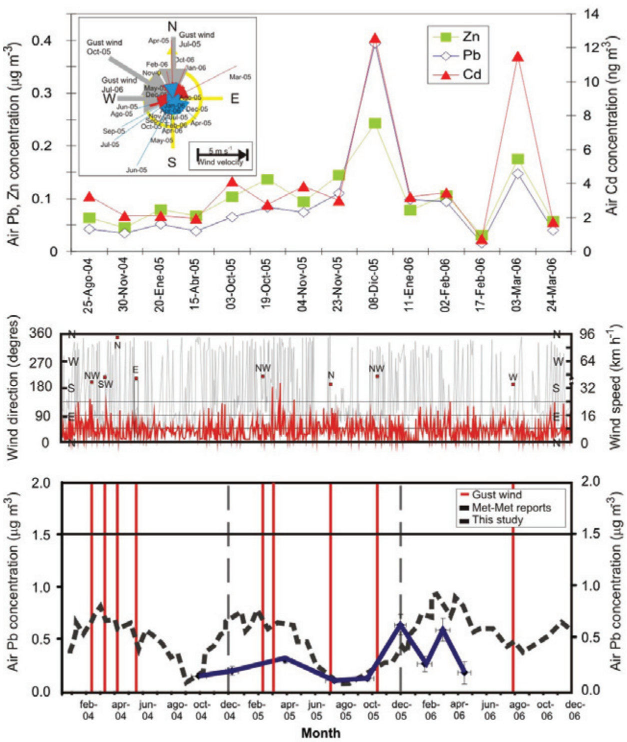

Figure 1. Cadmium, lead and zinc concentration in aerosols collected in the urban areas from Torreón. Wind speed and direction diagram for Torreon Airport, Torreón (NE Mexico).

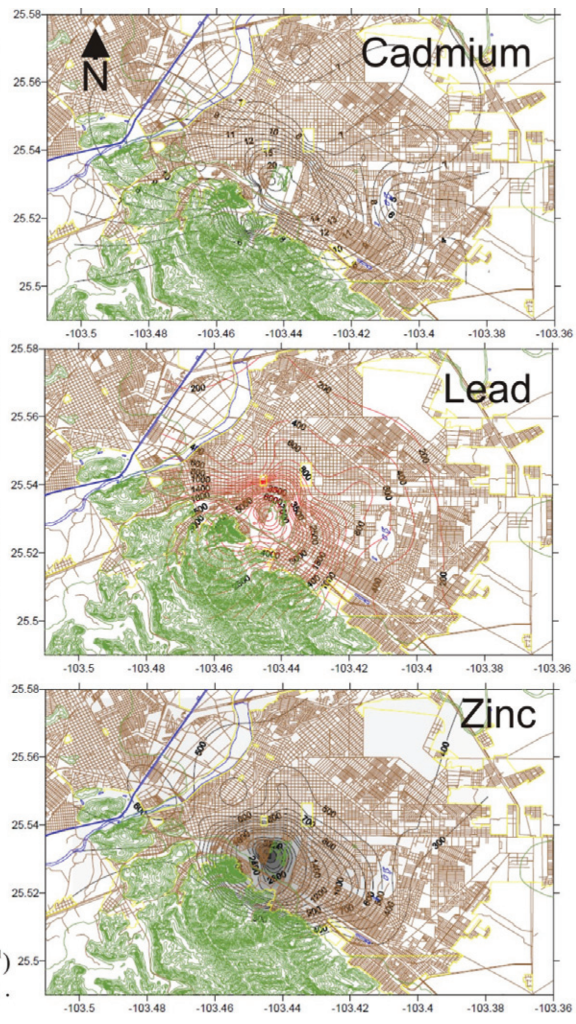

Figure 2. Cadmium, lead and zinc concentration (µg g^{-1}) in urban dust from Torreón .

4. Conclusions

According to the literature, the levels of Cd, Pb and Zn found in the urban area from Torreón could have consequences for human and environmental health. This study has important implications for other populations living in other smelter towns where remediation efforts have been undertaken or are proposed. The outcomes of such a study have direct relevance to regulatory authorities who are charged with attempting to mitigate the deleterious impact and health effects associated with non-ferrous metal processing.

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